Model-Independent Analysis of ring lattice

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March 1, 2002

Some references:

•C.X. Wang, M. Borland, V. Sajaev, K.J. Kim, “BPM system evaluation using model-independent analysis”, PAC01
•C.X. Wang, J. Iriwn, Y. Yan, “Computation of nonlinear one-turn maps from measurement with model-independent analysis”, PAC99
•J. Irwin, C.X. Wang, Y. Yan, et. Al., PRL 82(8), 1999.
•Chun-xi Wang, “Model-Independent Analysis of beam centroid dynamics in accelerators”, Ph.D. dissertation, Stanford University.

What is Model-Independent Analysis (MIA)

- It's statistical analysis (principal component analysis) of spatial-temporal modes in beam centroid motion recorded by the BPMs.
- It's mostly independent of detailed machine models.
- It's inclusive rather than exclusive. Various other data analysis methods such as Fourier analysis, map analysis, etc. (even machine modeling) are being incorporated.
- It's not a recipe for a specific measurement, instead, it's a new paradigm that facilitates systematic measurement/analysis of beam dynamics. Recipes have been developed for specific measurements, but there are a lot more to do and R&D are required.

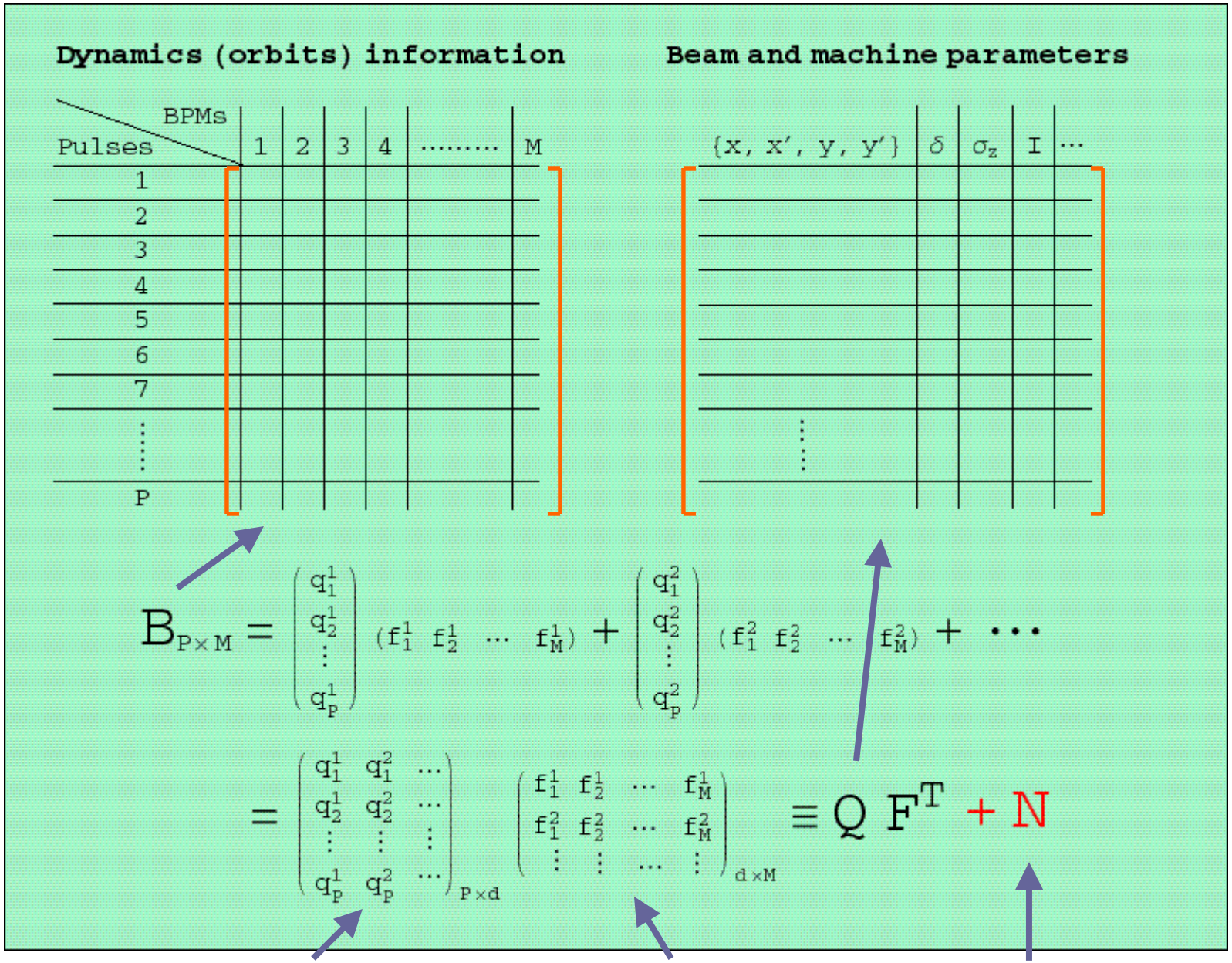
Advantages:

High sensitivity, model independent, quick and non-invasive, systematic

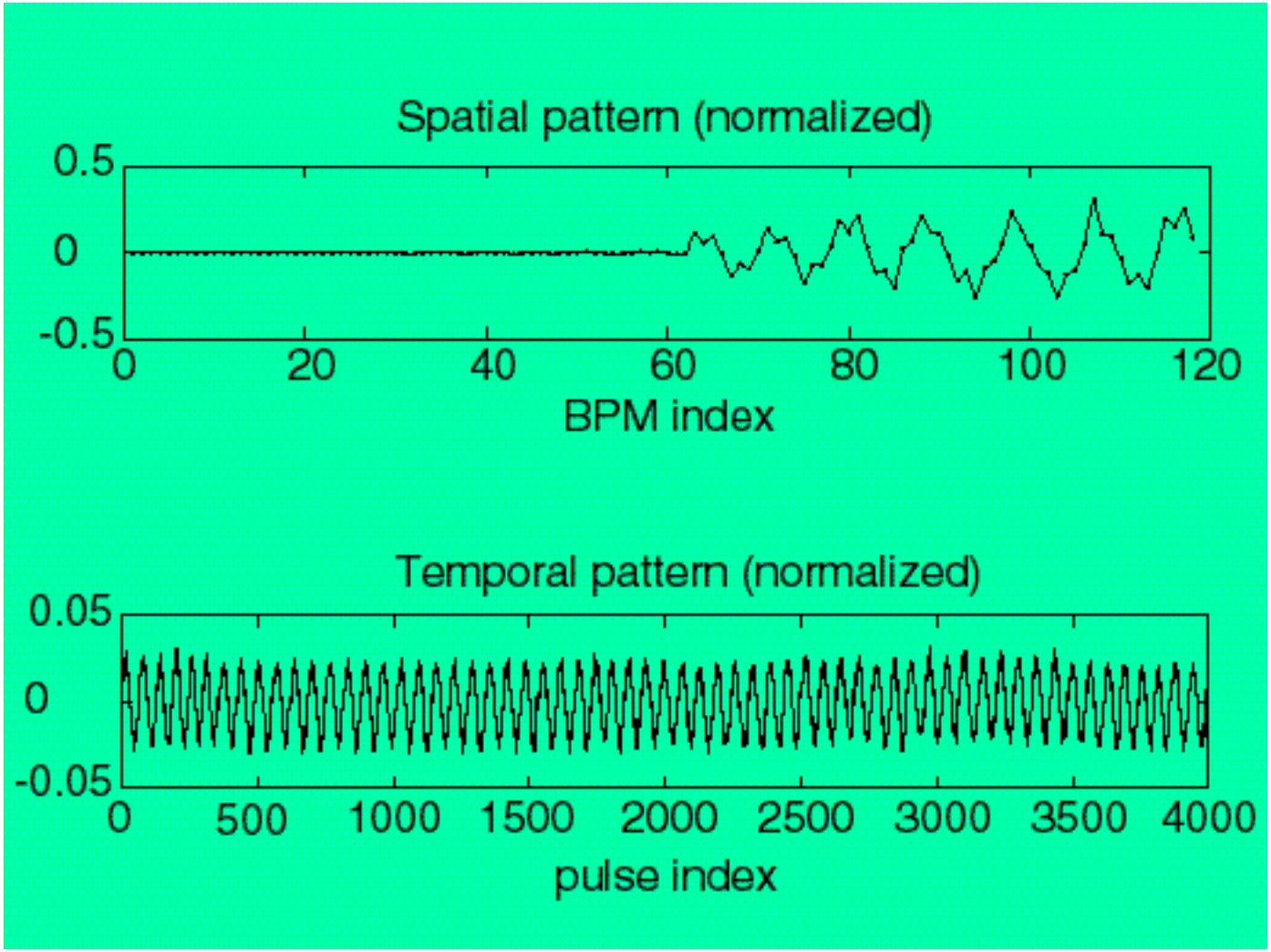
Basic requirements on instrumentations:

A large set of reliable turn-by-turn BPMs

Physical base decomposition of BPM-data matrices

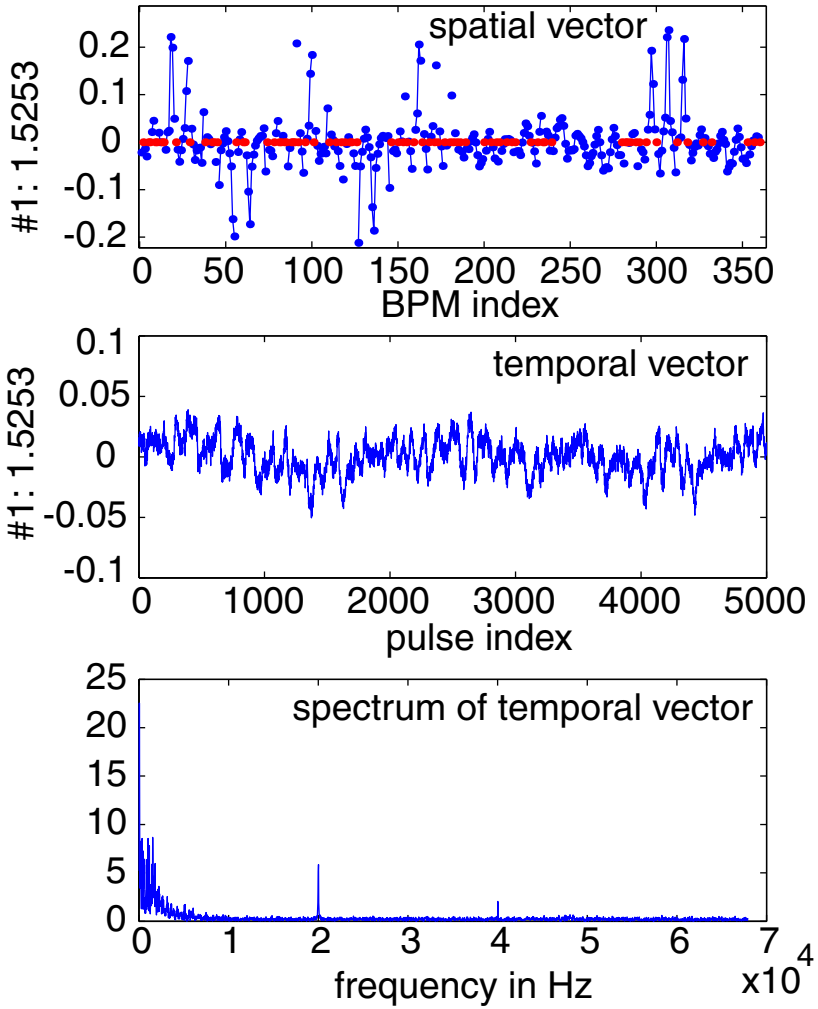


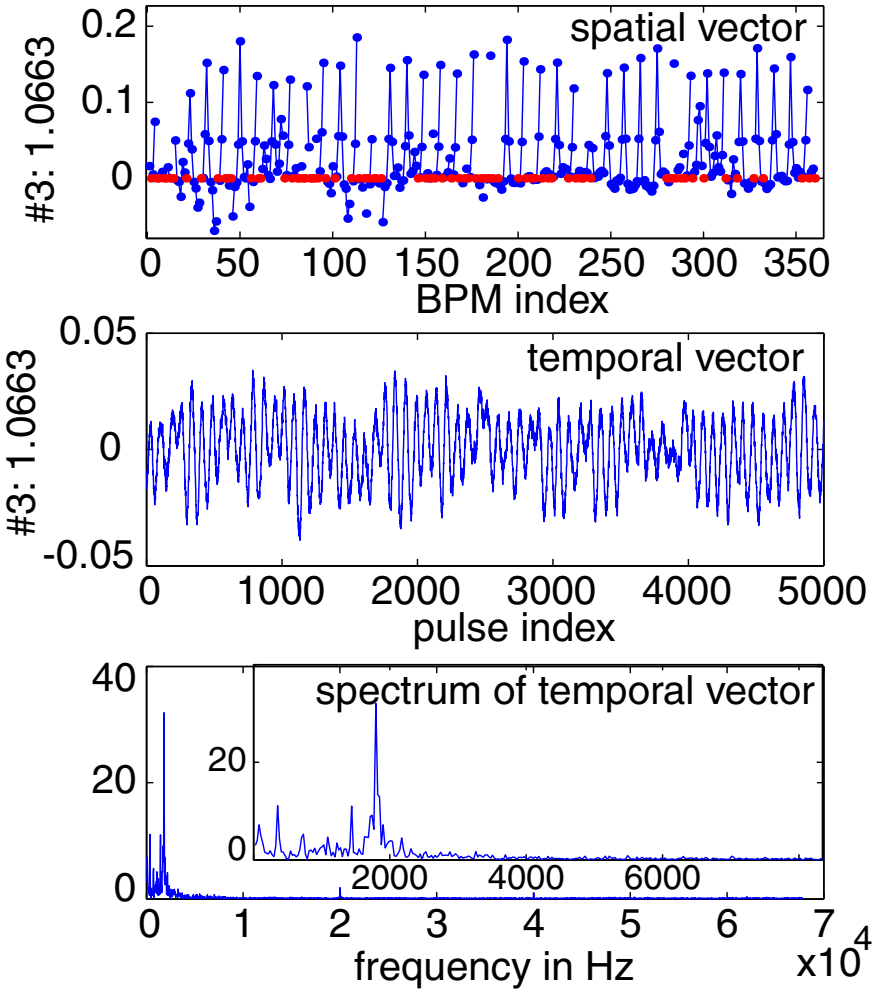
A physical mode due to a dithering corrector



Experiment done at SLC

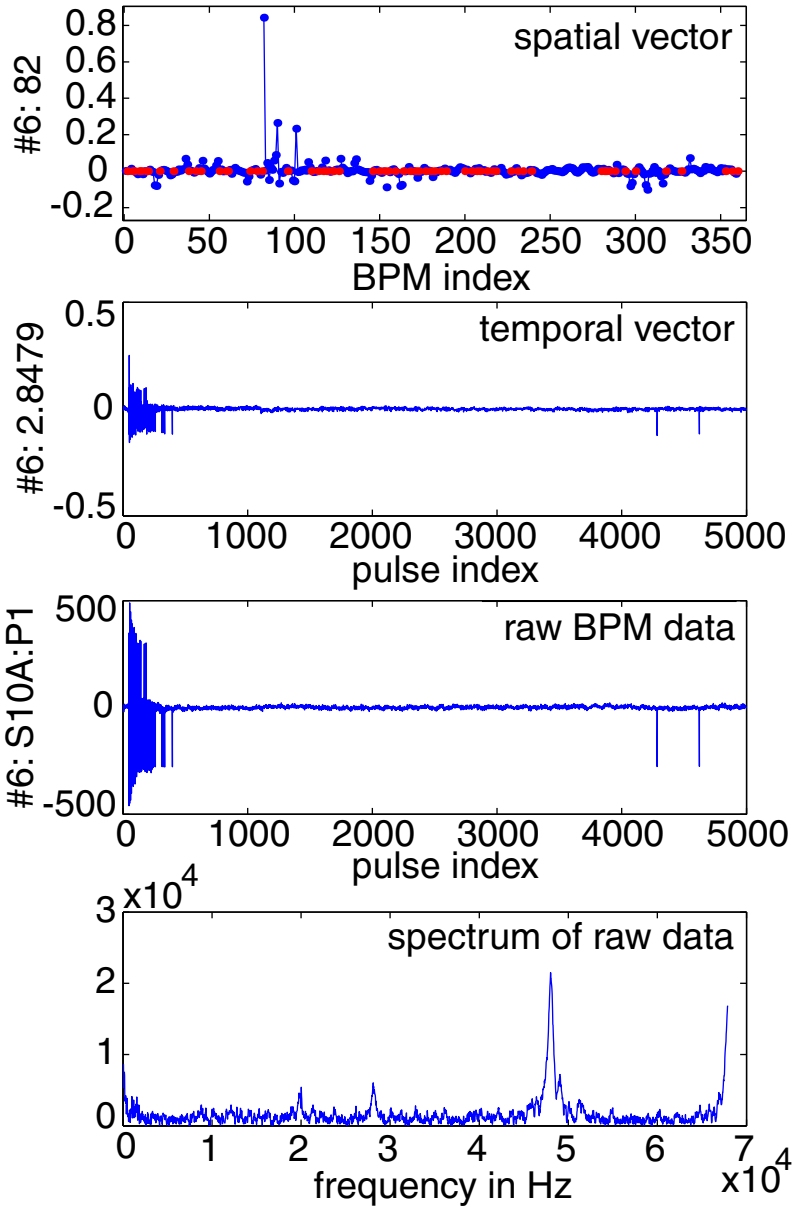
Examples of horizontal coherent modes in APS ring



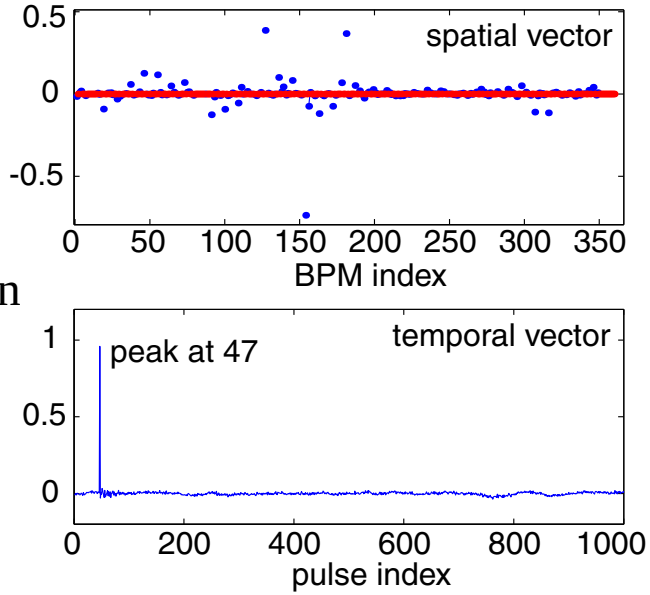


- Broadband low frequency noise and “chopper noise” at 20 and 40 kHz.
- Dispersion and unsettled longitudinal oscillation.

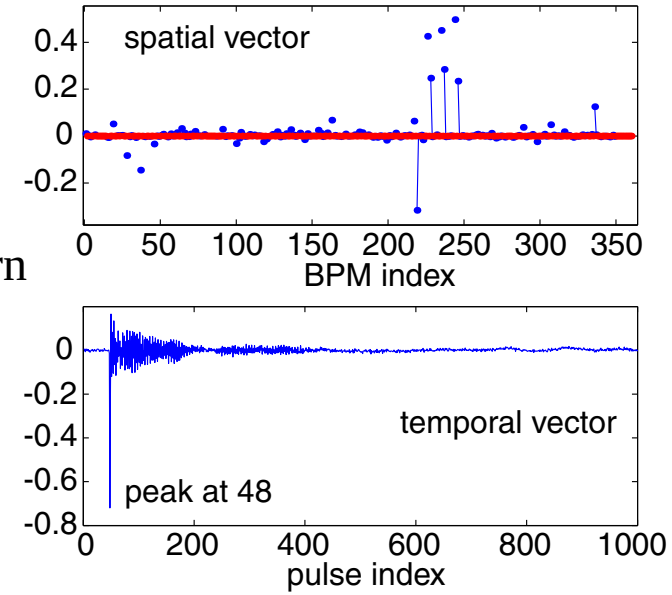
Examples of problems in BPM history of APS



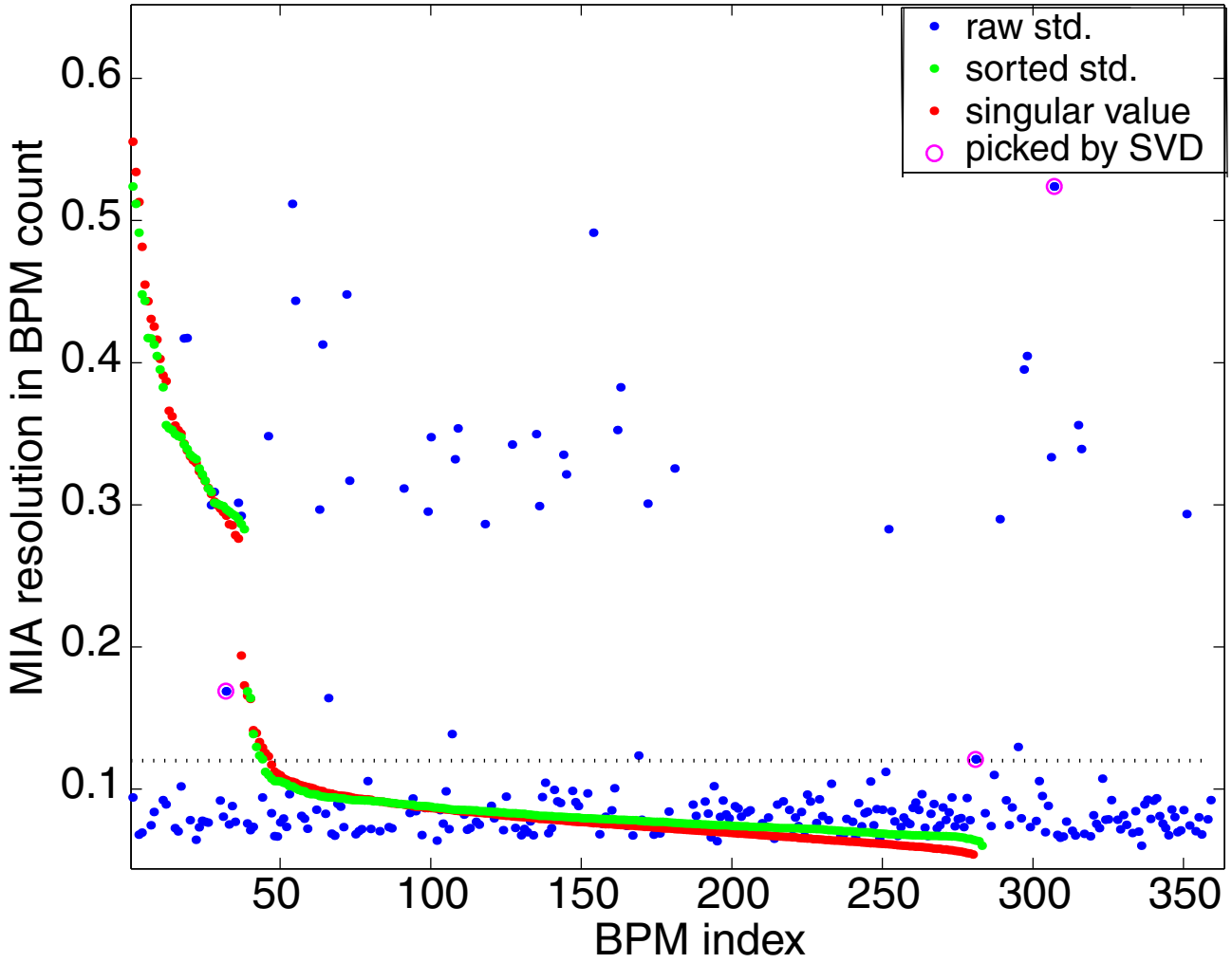
one-turn ahead



one-turn behind



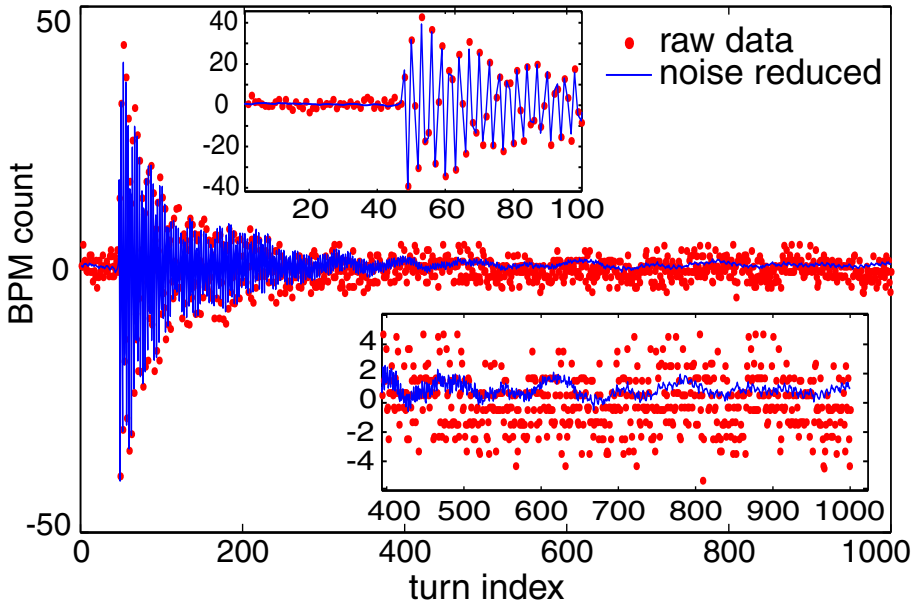
Measurement of horizontal BPM resolutions of APS



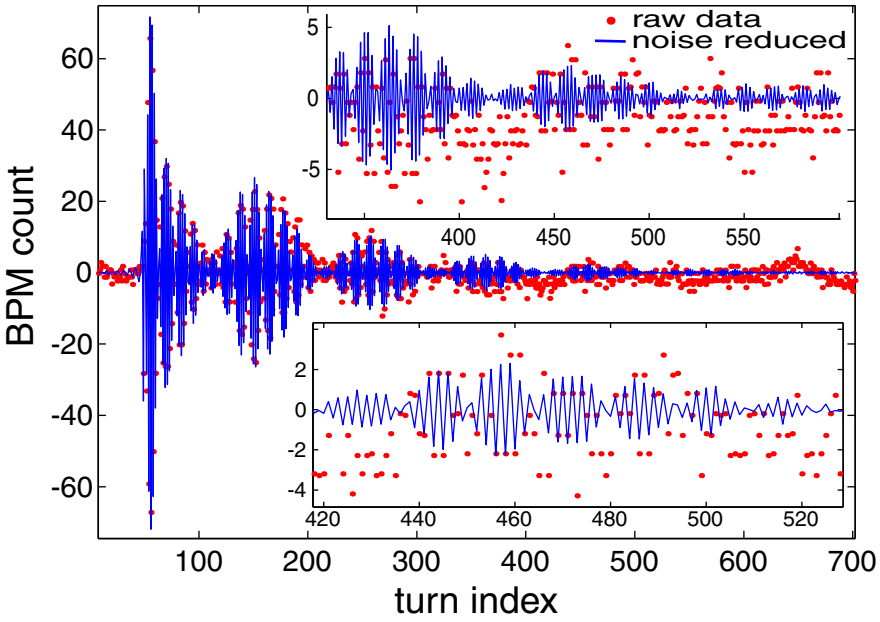
- Three coherent modes have been removed from the data.
- BPMs on the upper part have larger noise mostly due to using higher gains.
- The curves don't reach the end because many BPMs do not function at all.

Noise reduction of turn-by-turn BPM history data of APS

(horizontal)

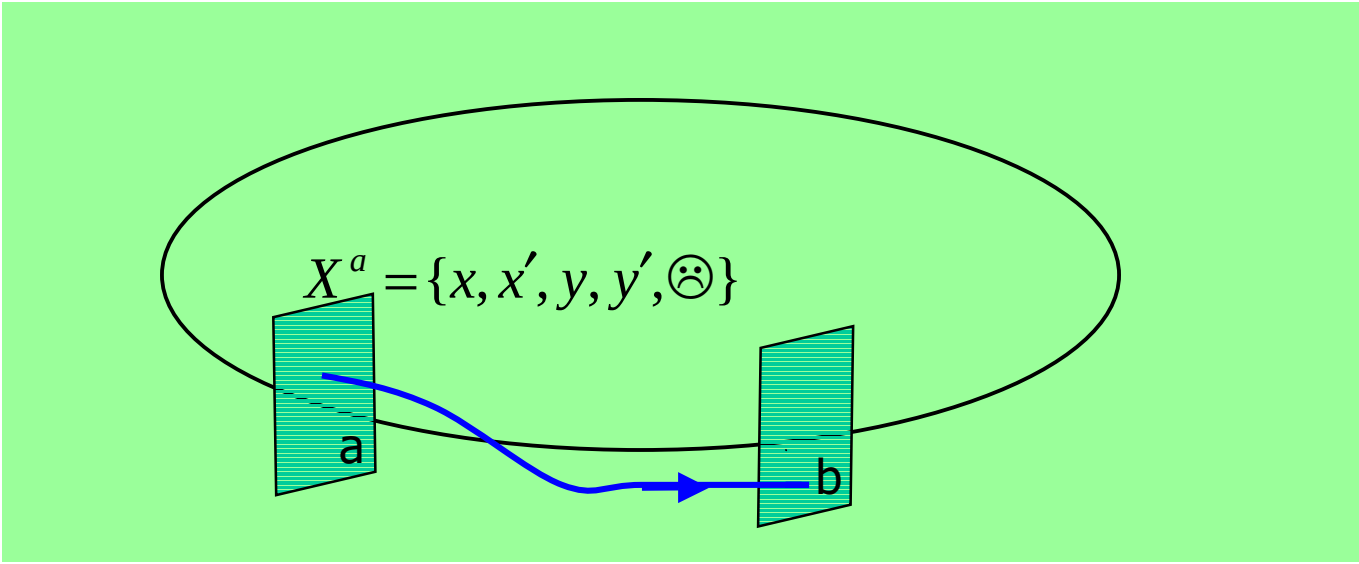


(vertical)



- These are the BPM history data of a horizontally and vertically kicked beam.
- After noise reduction, beam motion can be clearly seen beyond the gridlines of BPM digitization.
- One BPM count is about 7 μm.

Measurement of nonlinear transformation maps

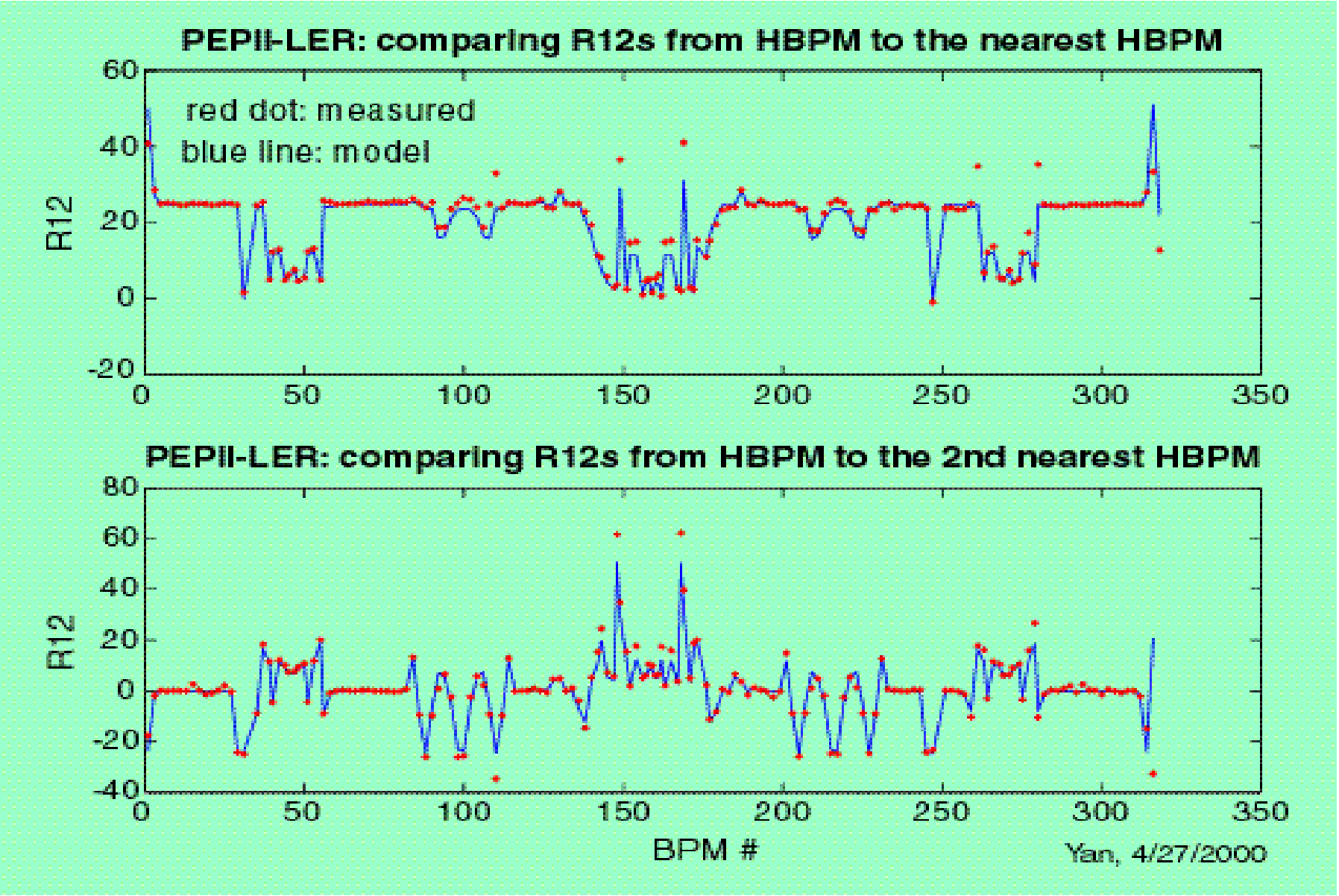


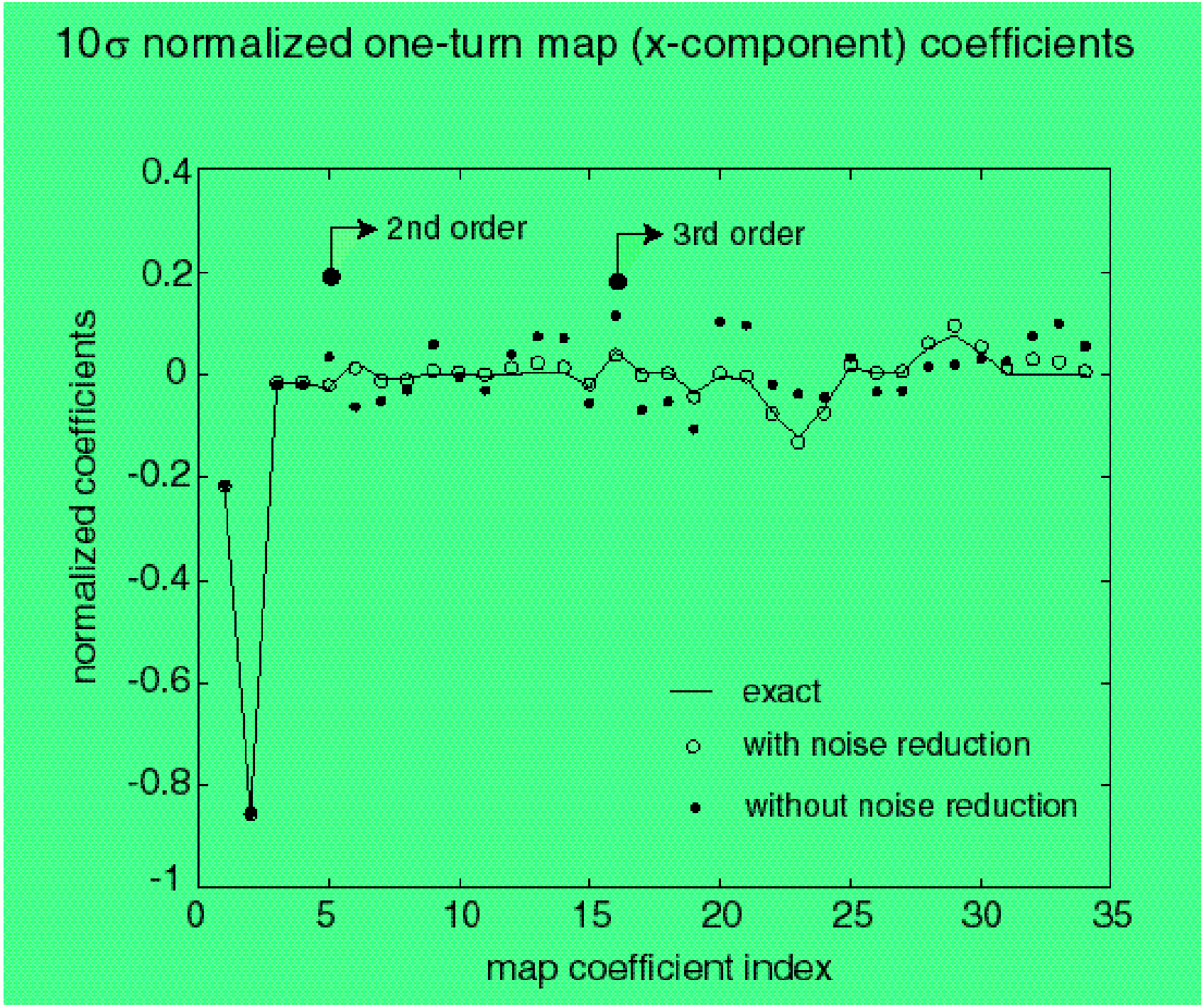
Taylor map representation (TRANSPORT notations)

$$X_k^b = C_k^a + R_{kl}^{a\to b} X_l^a + T_{klm}^{a\to b} X_l^a X_m^a +$$
$$U_{klmp}^{a\to b} X_l^a X_m^a X_p^a + V_{klmpq}^{a\to b} X_l^a X_m^a X_p^a X_q^a + ☹$$

Need high sensitivity to beam motion, for which MIA could be crucial

Local R12 measurement of PEP-II LER




10σ normalized one-turn map (x-component) coefficients
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
normalized coefficients
2nd order
3rd order
exact
with noise reduction
without noise reduction
0
5
10
15
20
25
30
35
map coefficient index

Transverse wakefield effect measurements at SLC